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Evaluating Adaptability and Yield Performance of Open Pollinated Maize Varieties in North Western Tigray

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Abstract

In order to evaluate the performance of improved maize genotypes, an experiment was conducted at Medebay zana and Laelay Adiabo district of North western of Tigray, Ethiopia, during 2014 and 2015 main cropping season. The experiment was laid out in a randomized complete block design with three replications. The data were recorded on plant height, ear height, number of ears/plot, plant and ear height, days to 50% anthesis, silking, maturity, grain yield and 1000 grain weight. All varieties showed significant differences with each other for all the traits studied in most environments but incase of genotype by environment combined data revealed most of the traits gave nonsignificant result and indicated better to focus and recommend on the stable genotypes across the environments. Variety Gibe-2 and Gibe-1 had the top two highest grain yield of 5114.15 kg ha^{-1} and 4964.96 kg ha^{-1}. Melkasa-6 was the early maturing variety as compared with standard checks of melkasa-2 and the remained varieties. The highest plant height and ear placement of 237.28, 120.80, respectively cm was noted in variety Gibe-1. This variety may be susceptible to lodging. These varieties had a wide genetic background, thus showing grain yield ranges from 1748 to 5114 kg ha^{-1}. So, generally maize variety of Gibe-1 and Gibe-2 were found most promising, which has the potential to increase the average yield of maize in Medebay zana and Laelay Adiabo districts and is therefore recommended to demonstrate for general cultivation in both districts.

Keywords: Maize; Grain yield; Genotype by environment interaction; Stability

Introduction

Maize (*Zea mays* L.) is one of the three most important cereal crops in the world together with wheat and rice in terms of area of production. The global maize production area 176 million hectares while that of wheat 216 million hectare and that of rice at 184 million hectares in 2012 [1]. However, maize surpasses both wheat and rice in terms of total grain production.

The productivity of the crop in developed countries such as in USA is 10.3 t/ha; in Germany 9.7 t/ha; in Canada 8.4 t/ha and South Africa 4.96 t/ha with the world average grain yield is 5.1 t/ha [2]. Maize contributes 34% of the protein and 35% of calories in Africa, with a 43 kg per capita for human consumption. In eastern and southern Africa alone, maize accounts for over 25% and 31% of the total calories consumed by human respectively with per capita annual consumption of 58 and 84 kg, respectively.

Maize is one of the most important cereal crops grown in the Ethiopia. The total annual production and productivity exceeds all other cereal crops. In terms of area coverage, it is only superpassed by tef [*Eragrostis tef* (Zucc.) Trotter][3]. Considering its importance, wide adaptation, total production and productivity, maize is regarded as one of the high priority food security crops in Ethiopia, the second-most populous country in sub-Saharan Africa after Nigeria [4]. Ethiopia's current average national maize yield is 3.43 metric tons per hectare whereas the developing and developed countries average yields are 2.5 and 6.2 metric tons per hectare, respectively [5].

Maize also occupies a strategic position in the food security of Ethiopia as in several countries in sub-Saharan Africa and the vision portends the intention of the government to transform the agricultural sector from a rural based economy to commercial and industry oriented sector in order to boost agricultural productivity, enhance food security and self-sufficiency. But there are some problems that hinder its production and productivity like lack of high yielder and stable improved genotypes, drought, change in soil fertility, inappropriate agronomic practices, soil erosion, decreasing applications of manure-based compost as a result of a government policy prohibiting farmers from collecting fodder from forests leading to reductions in the number of livestock per farm, and low adoption of new maize varieties with higher potential yield released by the national maize breeding programmes. Hence, a significant proportion of maize in Ethiopia is produced in both the low land and highland areas and its considerable variation in the grain yield is observed depending up on the variety, fertilizer use, rainfall pattern, frequency of tillage, plant density and the like.

In Ethiopia, maize is also grown at four different maize agro ecology zones (MAEZs) that are classified mainly based on altitude and precipitation: high altitude sub humid (1800-2400 masl), mid-altitude sub-humid (1000-1800 masl), low altitude sub-humid (<1000 masl) and low-moisture stress (500-1800 masl) [3]. So, maize is one of the most versatile emerging crops having wider adaptability under varied agro-climatic conditions. It performs well on well-drained fertile soils in areas with moderately high temperatures and adequate, but not excessive rainfall [6]. Maize is a warm weather crop and is not grown in areas where the mean daily temperature is less than 19°C or where the mean of the summer months is less than 23°C. Although the minimum temperature for germination is 10°C, germination will be faster and less variable at soil temperatures of 16°C-18°C. Under warm and moist conditions, seedlings emerge after about six to ten days, but under cool and dry conditions this may take two weeks or longer.

According to the report of central statistics authority [5] maize productivity reached 2.48 t ha^{-1} and north and north western Tigray leads highest productivity of maize and most widely grown in Medebay zana, Tahtay koraro and Laelay adiabo woredas of Tigray, Northen Ethiopia. In terms of hectarage, it ranks first in Laelay-Adiabo and second (next to tef) in Medebay zana. But in terms of its yield farmers get low amount from a given area of land mainly due to lack of adaptable and good yielding maize varieties, lack of improved agronomic practices etc. Although maize is this much important crop in these three woredas, no detailed research has been undertaken so far to replace the low yielding local varieties by the adaptable, high yielding and disease and pest resistant low land maize varieties. Several efforts are being undertaken by Maitsebri research center to secure food self-sufficiency at the household level. One of them is giving farmers good yielding and adaptable crop varieties to replace the old maize land races and recycled maize varieties. Hence the current study proposed with the following objectives:

To evaluate the adaptability and yield performance of the varieties.

To demonstrate and popularize best maize varieties in low and mid altitudes of areas.

Materials and Methods

Experimental design, treatments and trial management

The experiment was conducted in two main cropping season of 2014 and 2015 (June to Nov) at 2 different locations: viz Laelay adiabo and Medebay zana. These locations are different in soil type, altitude and mean annual rainfall. Hence, each location was considered as one environment. Seven maize genotypes were included in the study. The experiments were laid out in the randomized complete block design (RCBD) with three replications at both locations. Each plot comprised five rows of 4 m length with plant spacing between rows and within row 0.75 m and 0.25 m, respectively. Two seeds per hill were planted and later thinned to single plant per hill, at 2 leaf stage (V-2 stage) and then thinned to one plant per hill providing a uniform stand of about 53,200 plants ha^{-1}. Other management practices were done as per the recommendation made for crop at each location.

Data collection

Data were collected on major phonological, growth, yield and yield related traits as described below.

Phonological and growth data: Days to Anthesis (AD): The number of days from planting to when 50% of the plants in a plot will started to shed pollen.

Days to Silking (SD): This was recorded as the number of days from planting to when 50% of the plants in a plot produced 2-3 cm long silk.

Ears Per Plant (EPP): This was recorded as total number of ears harvested from a plot divided by the total number of plants in a plot at harvest.

Plant Height (PH): The height of from five randomly taken plants from harvestable row was measured from base of the plant to the point where the tassel starts branching and the average value was recorded.

Ear Height (EH): Ear height of from five randomly taken plants from harvestable row was measured from base of the plant to the upper most useful ear bearing node and the average value was recorded.

Days to Maturity (DM): This was recorded as number of days from planting to 50% of the plants in the plot reached physiological maturity (black layer formation).

Yield and Yield Related Traits: Number of ears/plant (NEP): This was recorded as the ration of the total number ears from five randomly taken plants from harvestable row and harvested to the total number of plants harvested.

Ear Length (EL) (cm): The length of five randomly taken plants from harvestable row ears was measured and the mean value was recorded per plot basis.

100 Kernel Weight (HKW) (g): One thousand kernels per entry was counted using electronic counter and then weighed using sensitive balance.

Grain Yield (GY): Grain yield per plot was converted to grain yield in t/ha after adjusting to 12.5% moisture.

Results and Discussion

Grain yield and some yield related traits

The analysis of variance for yield and yield related traits for location Laelay adiabo and Medebay zana are given in Tables 1 and 2 respectively. Analysis of variance showed significant differences for days to anthesis and maturity among the varieties in Laelay adiabo location as well as most of yield and yield related traits showed significant difference except days to maturity, ear length and ears per plant in Medebay zana site (Tables 1 and 2). The significance difference among varieties indicates the presence of variability for grain yield among the tested entries, which could be exploited for the improvement of the respective traits. The predominant component of genetic variation determines the choice of an efficient breeding method for incorporation of concerned genes into new materials [7]. Sofi and Rather also found similar results of genotypic difference for ear length (cm), ear diameter (cm), ears per plant, 100-seed weight (g) and grain yield per hectar (ton).

SN	Treat name	50%AD	50%SD	DM	PHt(cm)	EHt(cm)	CL(cm)	Ears/plant	100 swt(g)	Gy(kg/ha	BY(kg/ha)
1	Abo-Bako	74	82	122.7	183.1	78.7	17.7	1.6	26.4	5338	15085
2	Gibe-1	77.3	82	127.7	183.3	94.2	19.1	1.3	24.6	6124	17693

3	Gibe-2	74.3	80.7	127.3	248.3	124.2	22.9	1.6	34.5	7143	21468
4	Gambella comp1	74.3	80.3	120.7	216.9	102.6	18.4	1.3	28.6	4828	16110
5	Local red maize(check)	72	78	126.3	226.3	101.9	20.5	1.2	33.6	5583	18131
6	Melkassa-2 (S.check)	67	71	119.3	205.5	91.5	21.1	1.4	29.4	5494	15564
7	Melkassa-6	69	75.7	121	191.7	82.7	17.5	1.2	29.2	5119	15556
LSD		7.7	11.65	5.7	40.4	32.6	4.7	0.4	11.5	2746.9	8202
CV		5.8	8.3	2.6	10.9	19	13.6	16.4	22	27.3	27
F-test		**	Ns	*	*	Ns	Ns	Ns	Ns	Ns	Ns
Key: AD: Days to Anthesis; SD: Days to Silking; MD: Days to Maturity; PHt: Plant Height (cm); EHt: Ear Height (cm); CL: Cob Length (cm); GY: Grain Yield per ha; BY: Biomass Yield per ha; SC: Standard check variety; LSD: Least Significant Difference; CV: Coefficient of Variation. Ns: Non-significant.											

Table 1: Yield and Yield related performance of open pollinated maize varieties in Laelay adiabo, 2008. Means within the same column followed by the same letter are not significantly different.

SN	Treat name	50%AD	50%SD	DM	PHt(cm)	EHt(cm)	CL(cm)	Ears/plant	100 swt(g)	Gy(kg/ha	BY(kg/ha)
1	Local red maize	81.3	85.3	146	246.1	139.5	22.2	1.2	36.3	4721	16746
2	Melkasa-2	80.6	83.6	146	215.6	100.8	21.6	1.2	41.7	5775	16075
3	Abo bako	94	94	147.6	165.7	73.1	20.6	1.2	27	1467	10761
4	Melkasa-6	82.3	84.6	143.3	196	85.3	19.3	1.4	26.7	2924	9424
5	Gibe-1	91.3	96.3	147.6	265.8	139.8	20.1	1.1	54.7	5735	24775
6	Gibe-2	87	91	149.3	225.9	108.6	21.3	1.5	51.3	7107	21411
7	Gambella comp1	89.3	93.6	146.6	221.7	107.9	19.8	1.7	27	3146	10694
LSD		5.9	3.8	4.6	20.5	13.8	2.7	0.4	14.8	2154	7849
CV		3.9	2.4	1.8	5.2	7.2	7.5	17.1	22	27.5	28.1
F-test		**	**	Ns	**	**	Ns	Ns	**	**	**
Key: AD: Days to Anthesis; SD: Days to Silking; MD: Days to Maturity, PHt: Plant Height (cm); EHt: Ear Height (cm); CL: Cob Length (cm); GY: Grain Yield per ha; BY: Biomass Yield per ha; LSD: Least Significant Difference; CV: Coefficient of Variation; Ns: Non-significant.											

Table 2: Yield and Yield related performance of open pollinated maize varieties in Medebay zana, 2008. Means within the same column followed by the same letter are not significantly different.

Plant and ear height: All genotypes showed significant difference for plant height (Tables 1 and 2). Among the tested genotypes, Gibe-1 had the highest plant height (327.28 cm) followed by local, Gibe-2 and melkasa-2 with the values of 212.80, 203.22 and 200.27 cm respectively, while short statured plants of 177.47 cm were recorded in genotype Abo bako (Table 3). Hussain et al. [8] reported differential pattern of maize varieties for plant height, ear height, and ear placement traits are regularly assessed in maize breeding programs since they are closely related to plant lodging; i.e., higher the plant height (PH) and/or ear (EH) height and/or ear placement (EP) higher the probability of plant lodging. These traits presented similar pattern of variation as expected because they are highly correlated among themselves [9].

P#	Variety Name	50% AD	50% SD	MD	PHt	EHt	100_wt_g	GY_kg_ha
1	Abo bako	92.0d	95.00c	135.08c	177.47e	89.28b	106.69d	1748.77d

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2	Gambella comp1	89.5c	94.50c	136.25cd	196.37cd	94.13b	121.71cd	2599.14c
3	Gibe-1	88.75bc	94.75 c	137.58d	237.28a	120.80a	154.36ab	4964.96a
4	Gibe-2	86.58b	91.00 b	138.00d	203.22bc	97.00b	134.18bc	5114.15a
5	Local-red	76.92a	82.58 a	132.08a	212.80b	116.5a	168.80a	3987.47b
6	M-2	79.33a	83.67 a	134.42bc	200.27bcd	93.62b	142.77bc	4672.23ab
7	M-6	79.42a	83.33 a	132.75ab	187.87de	84.88b	148.82ab	2780.10c
Mean		84.64	89.26	135.17	202.18	99.46	139.62	3695.26
CV	Geno*Env't	3.6	2.8	5.9	7.9	13.5	17.7	23.5
LSD(0.05	Geno*Env't	4.9	4.042	4.14	26.2	21.958	40.46	707.78
F-test	Geno	*	*	*	*	*	*	*
	Env't	*	*	*	*	*	*	*
	Geno*Env't	Ns	Ns	Ns	*	*	Ns	*
Key: AD: Days to Snthesis; SD: Days to Silking; MD: Days to Maturity; PHt: Plant Height (cm); EHt: Ear Height (cm); CL: Cob Length (cm); GY: Grain Yield per ha; BY: Biomass Yield per ha; LSD: Least Significant Difference; CV: Coefficient of Variation. Ns: Non- significant.								

Table 3: Combined mean performance of OPV maize 2014 and 2015 cropping season Laelay adiabo and Medebay zana, 2015. Means within the same column followed by the same letter are not significantly different.

Ear height (cm): The variations in ear height (cm) in present investigations were found to be highly significant due to divergent maize genotypes. The Gibe-1 had maximum ear height (139.8 cm), while the shortest ear height was recorded in Abo bako (73.1 cm) at location of Medebay zana (Table 2). These results get sufficient validation from the findings of who found maize varieties which have variety ear placement, indicated good for further maize breeding [10].

Number of ears/plant: As indicated in Tables 1 and 2 Gibe-2 and Gambela composite-1 showed productive number of ears per plant with values of 1.6 and 1.7, respectively. Prolificacy has been associated to drought stress tolerance [11] and to stability of maize hybrids across environments [12]. Since in tropical maize growing areas short periods of lack of precipitation during the flowering time are frequent, prolificacy should be considered as an important trait in breeding programs for these regions.

100 seed weight (HKW): Grain weight is an important yield parameter and is vary from genotype to genotype. Data pertaining 100-grain weight (g) of the seven genotypes (Table 2) were significantly different at Medebay zana site. Maximum value for 100-grain weight was shown by Gibe-2 (37.50 g) in Laelay adiabo site where as local red maize (32.3 g) in Medebay zana location, while the minimum value was recorded in genotype Gibe-1 (24.6 g). These results are in line with the finding of [13] which used as good criteria in the selection process for high yielding maize genotypes. Similarly Devi et al. [14] reported that ears plant-1, ear length, 100-seed weight directly influence the grain yield and indirectly affect several other parameters.

Grain yield (kg ha^{-1}): Data pertaining to grain yield are shown in Table 2. Significant differences were revealed for grain yield among different genotypes used in this study. Genotype Gibe-2 showed higher grain yield (7107 kg ha^{-1}), while the genotype Abo bako produced lower grain yield (1467 kg ha^{-1}). Similar results were reported by Akbar [15] who evaluated and identified high yielding maize varieties among different genotypes tested, since the final goal of maize breeders are selection of high yielding genotypes.

Biomass yield (kg ha^{-1}): Biomass yield is one of the most important traits animal feeding especially genotypes which have stay green traits. As Tables 1 and 2 indicated Gibe-1, local and Gibe-2 had high biomass yielding varieties in both locations.

Combined analysis of variance of yield and yield related traits

The Combined analysis of variance showed that the effect of environments and genotypes for grain yield was significant ($p \leq 0.01$) (Table 3). The significant effect of environment is due to their variation in rainfall amount and seasonal distribution, temperature and soil type (Table 3). Therefore locations played a significant role in influencing the expression of these traits, especially grain yield, 100 seed weight, plant height and ear height. The genotype by environment was significant for silking date, grain and biomass yield while the genotype by environment was not significant for days to anthesis, silking and maturity, 100 seed weight, indicates that genotypes were not significantly interacted with location i.e., possibility of selecting stable and adapted variety based on high mean performance across locations. Kang and Gorman indicated that, a significant GEI for a quantitative trait such as seed yield can seriously limit the efforts on selecting superior genotypes for improved cultivar development. An ideal maize hybrid should have a high mean yield combined with a low degree of fluctuation under different environments. One of the most important goals of maize breeders has been to enhance the stability of performance of maize when exposed to stresses [11].

Summary and Conclusion

In Ethiopia cereals account for about 80% of the annual crop production and maize is the first in total production and yield per unit area and second in area coverage among all the cereals. Therefore, the present study was conducted to estimate adaptability and yield performance of seven maize varieties for grain yield and agronomic traits and resulted to study was to identify better performing varieties for grain yield and other agronomic traits at Laelay adiabo and Medebay zana during 2014 and 2015 main season and were evaluated using randomized complete block design with three replications.

The genotype by environment interaction is an important aspect in both, plant breeding programs and the introduction of new maize hybrids. Deitos et al., indicated that genotype × environment interaction (GEI) is important for plant breeding because it affects the genetic gain and recommendation and selection of cultivars with wide adaptability. On the other hand, different genotypes may have different performance in each region that can be capitalized to maximize productivity.

Based on information of single and combined data analysis of variance most of traits revealed significant difference at ($p<0.05$), indicating, which indicate the possibility of selection for improvement of yield and yield related traits. Since this exploration is a two year and two location trial, it is suggested to be evaluated in multi-location trial on large scale basis before their commercial cultivation of identified promising genotypes for grain yield and their stability over locations and seasons and then used for future breeding work and/or for large scale demonstration and popularization. Generally, even if the current result was gained from few environment Gibe-2 and Gibe-1 were relatively best varieties in grain yield and major yield related traits and better to recommend to demonstrate in farmer's field in the targeted areas(districts).

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